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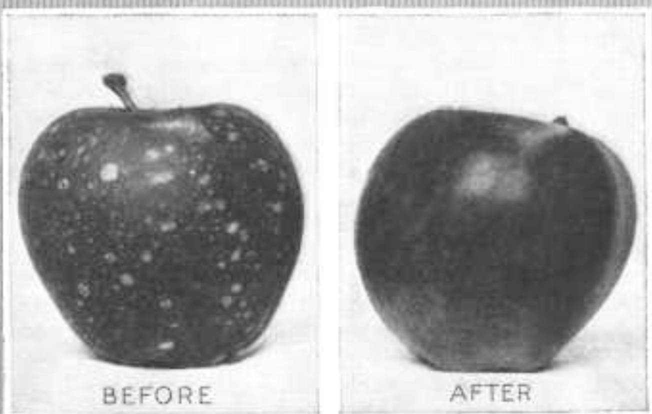
SPRAY-RESIDUE REMOVAL FROM APPLES AND OTHER FRUITS



SPRAYING to protect fruit crops, particularly apples and pears, from certain insect pests, frequently results in spray residues of lead, arsenic, or fluorine which must be removed to meet health requirements.

The difficulty of removing these residues is increased by dry, warm growing conditions; it varies with the frequency and character of the applications and the variety and maturity of the fruit.

Except for peaches, dry cleaning methods are not as effective or satisfactory as washing.

Solutions of hydrochloric acid and sodium silicate have been found to be satisfactory for washing. Hydrochloric acid is particularly effective for alkaline residues, as when lime is added to the sprays, and is more effective against fluorine residues than are alkaline washing materials. It may be used in either flood- or flotation-type washing machines. Its effectiveness in solution may be increased by increasing the concentration, by increasing the temperature of the solution, or by adding fortifying materials such as certain wetting agents, or a very light mineral oil. The latter is only effective in heated solutions and in flood-type machines.

Sodium silicate solutions when heated to 90° F. or above and used in flood-type machines are particularly suitable for fruit that has not been sprayed with lime or other alkaline materials, for that which has been sprayed with an insecticide to which oil has been added, or for fruit that has developed considerable wax.

The concentrations of these solutions may be tested by a simple titration, directions for which are given. Whether a treatment is effective with any particular lot of fruit can be determined only by analyses of the washed fruit.

With heated solutions temperatures of 90° to 120° F. may be used, depending on the variety and condition of the fruit, the time of exposure to the heated solution, and the kind of solution used. Exposure to heated solutions must be carefully controlled to avoid heat injury to the fruit.

Thorough rinsing, careful handling of the fruit, and frequent changing of the washing solution are also essential in safeguarding the fruit against injury. When these precautions are observed, the keeping quality of the fruit will not be impaired as a result of washing.

This bulletin is a revision of and supersedes Farmers' Bulletin 1687, Removing Spray Residue from Apples and Pears.

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SPRAY-RESIDUE REMOVAL FROM APPLES AND OTHER FRUITS

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INTRODUCTION

SPRAYING with lead arsenate has been for many years the most effective and economical means of controlling the codling moth on apples and pears. Other arsenical sprays and sprays containing fluorine have also been used. Fruit sprayed with these materials bears at harvest residues that may be injurious to health, and excessive amounts must be removed.

The United States Department of Agriculture has established regulatory tolerances for arsenic, fluorine, and lead. These tolerances for the year 1935 are: 0.01 grain arsenic as arsenic trioxide, 0.01 grain fluorine, and 0.018 grain lead per pound of fruit.

The desirability of using, for the control of the codling moth, a spray material that is nontoxic to humans is apparent, as it would not only eliminate the possibility of hazard to public health but would also relieve the fruit grower of the expense and trouble of washing the fruit. In recent years considerable effort has been made by the United States Bureau of Entomology and Plant Quarantine and other agencies to discover and develop substitutes for lead arsenate. Up to the present time no substitute has been found that is nontoxic to humans, effective in controlling the codling moth, and economically feasible. Until such a substitute is found the fruit grower must continue to rely on lead arsenate or other toxic materials and remove the excessive residue.

In spray residue-removal work previous to 1933 emphasis was placed on the removal of arsenic on the assumption that lead was removed in the same proportion as the arsenic. This was done because

of the difficulty of accurately determining the amount of lead on the fruit. The use of certain washing solutions, particularly certain alkaline solvents, however, resulted in lead residues out of proportion to the arsenic residues. The development of more rapid methods for the determination of lead and the establishment of regulatory tolerances for lead and fluorine reopened the question of spray residue removal with particular emphasis on methods for removing lead and fluorine residues.

Because of the increasing difficulty of controlling the codling moth, heavier and more frequent applications of spray have been made, and oils and other stickers have been added to the sprays. This has increased the difficulty of spray residue removal and has emphasized the need for more effective removal methods.

In the East and Central West many growers are just beginning to wash the fruit. In general, they require directions in regard to the methods of fruit washing most applicable to conditions east of the Mississippi.

Experience has shown that dry wiping or brushing cannot be depended on to remove appreciable quantities of spray residue, and this bulletin therefore will deal only with spray-residue removal by washing.

WASHING APPLES

RELATION OF CLIMATIC CONDITIONS TO SPRAY-RESIDUE REMOVAL

The warm, arid conditions prevailing during the growing season in the irrigated valleys of the Pacific Northwest are favorable to the development of the codling moth, and more cover sprays are usually applied there than in the fruit-growing districts of the Central and Eastern States. Thus, less spray material is usually applied to the trees under eastern conditions, and much of that applied is washed off by the relatively frequent summer and fall rains so that at harvest the amount of residue and consequently the difficulty of removal is usually less under eastern conditions than it is in the irrigated sections of the West.

Although weather conditions in the irrigated sections are favorable to the development of the codling moth they are not favorable to the development of apple scab or bitter rot; consequently, fungicides or lime to prevent arsenical burning are not commonly used there. The use of lime, or fungicides containing lime, as practiced in the East probably increases the amount of weathering and may facilitate removal with acid washing solutions, but it makes alkaline washing solutions such as sodium silicate relatively ineffective. In many respects, therefore, the problems of spray-residue removal under eastern conditions are quite different from those in the irrigated valleys of the West and will frequently be discussed separately. In the remainder of this publication the expression "northwestern conditions" will refer to conditions that prevail in the irrigated valleys of the West and "eastern conditions" will refer to conditions in other parts of the country where considerable rainfall normally occurs during the summer and fall.

Annual differences in climatic conditions prevailing in a given district may also influence the difficulty of residue removal. Thus, following an exceptionally rainy season, most of the spray material

may be washed from the fruit and little or no additional cleaning be required at harvest. On the other hand, in an exceptionally dry season abnormally heavy residues at harvest may result, with greater difficulty in removal.

Although rainfall is probably the principal climatic factor influencing spray-residue removal, temperature may also be a factor. Under abnormally warm conditions an earlier or heavier wax development may take place that may retard residue removal.

RELATION OF SPRAY TREATMENT TO SPRAY-RESIDUE REMOVAL

The method of washing and the difficulty of spray-residue removal is intimately associated with the spray program followed. In planning a spray program consideration should be given both to the effective control of the codling moth and to the possibility of effective spray-residue removal. It should be emphasized that omitting late sprays or applying substitute sprays in an attempt to avoid the necessity of fruit washing may result in heavy losses from wormy fruit. On the other hand the possibility of complications in washing should also be kept in mind and, if possible, sprays that may make cleaning difficult should be avoided.

The adoption of sanitary measures such as scraping and banding the trees, removing rubbish, and sterilizing old boxes or baskets before they are distributed in the orchard reduces the codling moth population and may make the application of less spray material possible, thus simplifying the removal problem.

Whether a given spray treatment makes washing more difficult depends on the method of washing or the solvent employed; conversely, the solvent that can be most effectively used may be determined by the spray treatments given. The two cleaning agents that have proved most satisfactory are hydrochloric (muriatic) acid and sodium silicate, the latter being an alkaline material. These are the basic materials although each may be made more effective by the addition of other materials. As mentioned previously, the use of lime or fungicides containing lime in the cover sprays leaves an alkaline residue on the fruit that makes an alkaline wash such as sodium silicate relatively ineffective. For this reason hydrochloric acid is indicated for the washing solution under eastern conditions. The use of alkaline materials, such as calcium arsenate or manganese arsenate, in the cover sprays also makes hydrochloric acid more effective as a washing solution. On the other hand, where lime is not used in the cover sprays washing with sodium silicate may be more effective with certain spray treatments, such as those in which fish oil or mineral oil are used.

Under eastern conditions 4 to 5 cover sprays of lead arsenate at the rate of 3 pounds to 100 gallons are usually applied to fall and winter varieties of apples. To the first or first and second treatments with these sprays is usually added lime-sulphur, and to the later treatments bordeaux mixture or lime. Following such a program, the residues at harvest are normally not greatly in excess of the tolerance and usually can be readily removed by washing with a hydrochloric acid solution at room temperatures. The addition of fish oil (1 quart to 100 gallons) or mineral-oil emulsion (1 gallon to 100 gallons) to the first two cover sprays does not appreciably influence the residues at harvest or

the difficulty of removal. It should be noted in this connection that as mineral oil cannot be used with lime-sulphur, bordeaux must be used as the fungicide if mineral oil is used, and there is danger of burning from bordeaux if cool, wet weather prevails. The addition of calcium caseinate spreader or fish oil (1 quart to 100 gallons) to the late cover sprays of lead arsenate may increase the amount of residue at harvest but may not make removal more difficult with acid washing solutions under eastern conditions. The addition of mineral oil (1 gallon to 100 gallons) to the late cover sprays materially increases the amount of residue at harvest and the difficulty of removal with acid solutions. Following such a program the addition of a wetting agent to the acid solution, or a heated solution with a wetting agent or a light mineral oil may be required for effective cleaning. When calcium arsenate is substituted for lead arsenate in some or all of the cover sprays the residues at harvest may be somewhat lower but the necessity for cleaning is not usually avoided and the control of the codling moth may be less effective together with increased danger of spray burning to the tree and fruit. Under eastern conditions little is known relative to the use of fluorine sprays in relation to the spray-residue problem. The indications are that, with present methods of washing, fluorine residues are removed with greater difficulty than are lead arsenate residues.

Under northwestern conditions from 6 to 8 cover sprays are usually applied to fall and winter varieties of apples for the control of the codling moth. When lead arsenate alone, at the rate of 3 pounds to 100 gallons, is used throughout the season, heavy residues that are difficult to remove are usually encountered at harvest. The addition of fish oil (1 quart to 100 gallons) to the late sprays of lead arsenate may increase somewhat the difficulty of removal with hydrochloric acid, but it facilitates removal with sodium silicate solutions. The addition of mineral-oil emulsion (1 gallon to 100 gallons) to late cover sprays greatly increases the difficulty of removal. By omitting lead arsenate from some of the last cover sprays and substituting mineral oil and nicotine sulphate, the amount of lead residue at harvest will be reduced, but the difficulty of its removal may be as great as when lead arsenate without the oil is used throughout the season.

Fish oil or mineral oil are commonly applied with cryolite or other fluorine sprays, and when such sprays are used throughout the season the fluorine residues are usually very difficult to remove by the washing methods in use. The use of lead arsenate sprays during the early part of the season and of fluorine sprays with oil in the last two cover sprays reduces the load of lead and fluorine as compared with a complete program of either and may make cleaning easier with flood-type machines. Because of the difficulty of removing fluorine residues, not more than two late sprays of fluorine compounds should be applied. Flotation-type washers are relatively ineffective in removing fluorine residues.

RELATION OF VARIETY AND MATURITY TO SPRAY-RESIDUE REMOVAL

Varieties vary considerably in the amount of spray retained during the growing season and in the difficulty of cleaning after harvest. These differences are probably associated with differences in the roughness of the skin and the quantity and quality of the wax

that develops. Varieties also differ in their ease or difficulty of cleaning, depending on their maturity and the method of cleaning used. Varieties that develop considerable wax, such as Arkansas (Mammoth Black Twig), Arkansas Black, York Imperial, and Winesap, are likely to be relatively difficult to clean with acid solutions, particularly if fairly ripe when washed. On the other hand, such varieties are probably not more difficult to clean with sodium silicate solutions than other less waxy varieties, as wax development does not interfere with removal with such solutions.

The development of waxy or oily materials on the surface of the fruit takes place throughout the growing season, but becomes particularly noticeable during the harvest season and especially after harvest as the fruit approaches a ripe condition. This waxy deposit interferes with cleaning when acid solutions are used, but it may facilitate removal with sodium silicate solutions. When lime is not used in the cover spray, sodium silicate is indicated for the cleaning solution with waxy varieties of ripe fruit. When acid is used as the washing agent, the fruit should be washed promptly after picking or should be placed in cold storage to retard wax development until washed. Where both tender varieties and those developing wax have to be cleaned it may be desirable to use acid as the cleaning solution during the first part of the harvest season and sodium silicate solutions with the later more waxy varieties.

TYPES OF FRUIT-WASHING EQUIPMENT

The choice of washing equipment will depend on the quantity of fruit to be washed, the kind of washing solution used, and the difficulty of cleaning the fruit.

DIPPING TANKS

For the small grower who has only a few hundred bushels of fruit to clean an expensive commercial machine is, of course, out of the question. Under such circumstances dipping tanks that will effectively remove the residues likely to be encountered may be constructed at relatively small cost. Such equipment should consist of two similar tanks, one used for the washing solution and the other for the rinsing bath. The tanks should be large enough to accommodate one or more crates, depending on the capacity desired, and should be connected by a drain board to permit the excess washing solution to drain back into the wash tank before the fruit is dipped into the rinse tank. Slatted crates, or boxes with weighted removable covers, are convenient containers to use in the tanks. Hydrochloric acid should be used as the washing solution in dipping tanks. The concentration and time of exposure necessary will depend on the difficulty with which the spray residue is removed. Usually it is sufficient to use a concentration of 1 percent hydrochloric acid and to expose the fruit to the acid solution for 2 to 3 minutes. With varieties of apples that have open calyx tubes, such as Stayman Winesap, there is danger of the wash solution penetrating to the core and causing decay. This method of washing is laborious and inconvenient and is recommended only when the quantity of fruit to be cleaned is too small to justify the use of more expensive equipment.

FLOTATION-TYPE WASHERS

In the flotation type of washer the fruit floats through the tanks on the surface of the solution and is turned and submerged occasionally by means of slowly revolving paddles or by cloth drapes or brushes hanging down in the solution. The fruit may be pushed through such machines by feeding in additional fruit, by the paddles, by slat conveyors, or by other means. Machines of this type are simple and relatively inexpensive. They are economically feasible for the small grower with only a few thousand bushels of fruit to clean but can also be obtained in large sizes with capacity for washing 2,000 to 3,000 bushels per day and can be used in large orchards or in packing houses. They can be recommended where the difficulty of residue removal is not too great and where acid solutions are particularly applicable as

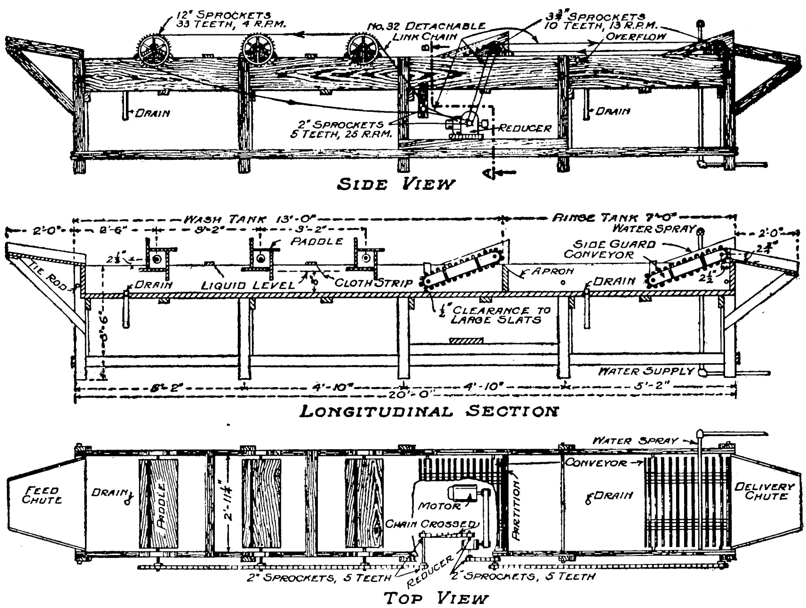

FIGURE 1.—Drawings of modified paddle washer.

under eastern conditions. They are relatively ineffective with fluorine-spray residues. Most flotation washers are not suitable for pears, as most varieties of pears will not float in water.

This type of cleaning equipment can be obtained from commercial manufacturers or can be home-made. Plans for the construction of a paddle washer of this type are given in figures 1 and 2. This machine is a modification of the citrus washer designed by the United States Department of Agriculture in 1925, and differs from the adaptation of that washer by the Oregon Agricultural Experiment Station in using conveyors instead of paddles to take the fruit from the tanks. Short lengths of conveyors in place of the lift paddles are slightly more expensive, but the elimination of the binding and catching caused by these paddles, as they are often constructed, is well worth the additional cost.

The conveyor shown in figure 2 is about the shortest that will satisfactorily remove the apples from the tank. Machine bolts, nuts, and washers are desirable means of attaching the hardwood slats so that they can be removed easily. Iron bolts, nuts, and washers will last longer in the acid than those made of brass. If the sprockets for this part of the equipment, and the driving mechanism as well, can-

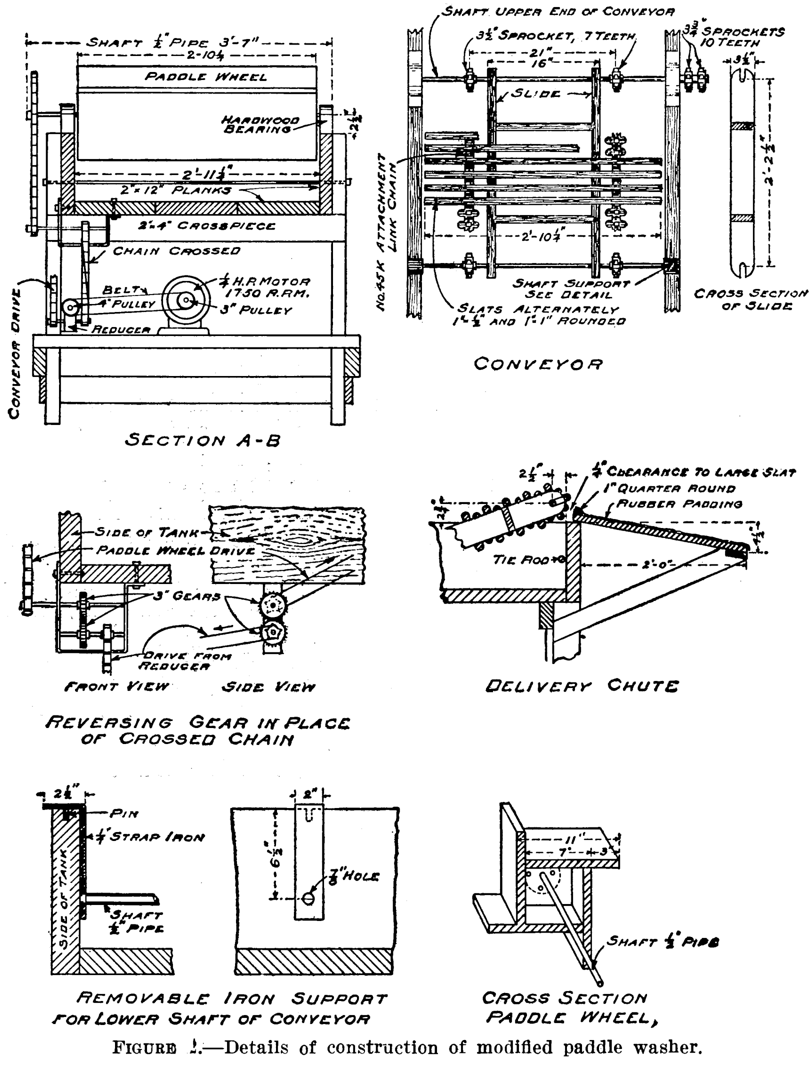

FIGURE 2.—Details of construction of modified paddle washer.

not be procured from the factory with the face of the teeth beveled to about 30°, they should be ground before being installed. If the teeth are left square, the chain will hang to the sprockets, especially on the smaller sizes, and a great deal of trouble in driving them will result. In making the slide around which the conveyor moves, a

slot should be made for the upper shaft in the sideboards, as indicated also in figure 2, to facilitate putting the conveyor in place.

The distances from the center of the upper shaft to the top and to the end of the tank are important in delivering the fruit from the ends of the conveyors. These distances, as shown, should be 2¾ inches from the top and 2½ inches from the inside end of the tank. A piece of automobile-tire inner tubing stretched at an angle from the end of the conveyor into the rinse tank will roll the fruit toward the end of the other conveyor and thereby reduce the chances of its being bruised by falling from the end of the conveyor onto fruit floating beneath in the rinse water. A chute made of ⅞-inch boards resting on a ⅞-inch crosspiece that is nailed to the top of the tank gives about the right height for delivering the apples from the conveyor. A piece of 1-inch quarter-round molding nailed across the end of the chute, clearing the largest cleat by a quarter of an inch, will aid in rolling the apples from the end of the conveyor with a minimum of bruising. A pitch of about 2½ inches in 2 feet will keep the fruit rolling on the chute. The piece of molding and the chute should be well padded with inner tubing or other material. The lower shaft of the conveyor is hung from the sides of the tank with 2-inch by ¼-inch strap iron and held in place by pins which fit into holes in the sides of the tank. This method of holding the conveyors enables them to be raised from the tanks when not in use, and thus reduces the corrosion from the acid and water, and facilitates cleaning the tanks. The clearance from the bottom of the tank to the large slats on the conveyor should be about one-half inch. A conveyor speed of 10 to 15 feet per minute will remove the fruit from the tanks fast enough to prevent its piling up.

The tanks are conveniently made of 2- by 12-inch material, with the wash tank 13 feet and the rinse tank 7 feet long, making a length over all of about 24 feet, including both feeding and delivery chutes. The machine described is only 3 boards wide, but if a larger capacity is needed, adding 1 or 2 boards to the width will increase the cost only slightly and will increase the capacity one-third and two-thirds, respectively. By using bolts, as indicated in figure 2, the tank can be drawn together. The edges of the boards should be first painted with asphalt paint to give tight seams. If the inside of the tank is painted, asphalt and not lead paint should be used, as the acid attacks lead. The shafts for the conveyors and submerger paddles are made of ½-inch pipe. This dimension refers to the inside diameter of the pipe, the external diameter being slightly less than seven-eighths of an inch. The shafts for the submerger paddles and those for the driving end of the conveyor are 43 inches long.

A convenient and economical way to fasten the submerger paddles to the shaft is with floor flanges for rail fittings, procurable at any plumbing shop. Those made for ¾-inch pipe will fit over the ½-inch pipes and can be fastened to them by driving a pin in a hole drilled through the collar of the flange and the pipe.

The machine, as shown, is 42 inches high. This height is adapted to the usual height of graders, but the tank may be somewhat higher if the fruit is dumped into it by hand. The capacity of the acid tank in the machine, constructed according to the accompanying plans, is about 180 gallons when filled to the recommended depth of 8 inches,

while the rinse tank holds about 100 gallons. The fresh-water spray on the end conveyor is a very important feature and should supply from 2 to 3 gallons of fresh water per bushel or box of fruit washed. The cloth strips hung across the wash tank should preferably be made of heavy cloth and should be about 2 inches wide and long enough to allow about 3 inches to hang on the fruit as it is floated through the tank, thus turning it as the cloths cling to the apples while they move. These strips add to the efficiency of the machine by giving the fruit a longer and more complete exposure to the acid and are of some value in removing insect specking, dirt, and lime-sulphur residue.

The sprockets, pulleys, and speeds shown in the plans are based upon a motor speed of 1,750 revolutions per minute with a 60-cycle current. A ½-horsepower motor has been found large enough to run this machine. The reduction gear used, although smaller than recommended, transmitting only $\frac{1}{16}$ horsepower, gave no signs of wear in a test run of about a month. A larger unit equipped with ball or roller bearings and transmitting ¼ horsepower would provide a desirable margin of safety in operating the machine season after season. The gears and bearings must be kept well oiled. While the reduction in speed can be made by using a combination of sprockets or pulleys, the reduction gear will be about as economical when the installation of extra shafts and the cost of the additional gears or sprockets are considered. A no. 32 chain is used for driving, while the conveyor chain is no. 45–K–1 attachment link chain. All sprockets are equipped with set screws instead of keys.

If a gasoline engine is used as a source of power, a combination of sprockets or pulleys can be used to obtain the proper speed reduction.

When built according to the accompanying specifications, the machine has a capacity of about 80 bushels an hour when the fruit is left in the wash solution for 2 to 3 minutes, which is about the desired time for most fruit although a 1-minute exposure may be effective for many lots of fruit. If the fruit is fed into the machine faster, more can be washed in a given time, the rate of feeding regulating the time in the acid and the resulting capacity.

The material and equipment (table 1) for the entire paddle-washer machine will cost about $150, including the motor and reduction gear. One carpenter should be able to build the tank and submerger paddles in about 3 days. The time necessary for putting the conveyor together and installing the driving mechanism will depend on the mechanical ability of the individual, but the mechanism is simple enough to offer no great difficulty if the specifications are followed.

The speed-reduction gears of the larger size have driving shafts three-fourths of an inch in diameter, while the size transmitting one-sixteenth horsepower has a ½-inch driving shaft. In ordering the sprockets for this part of the driving mechanism, the size of the bore should be specified.

The chain, sprockets, and speed-reduction gears can usually be obtained through a local dealer in hardware or farm machinery. Because of possible delays in getting the material shipped and difficulties that may arise in making the machine, orders should be placed early enough to allow the construction of the machine to be begun some time in advance of the packing season.

TABLE 1.—*Materials for a paddle-washer machine*

Description	Pieces or quantity	Size	Use
Plank	5 pieces	2 by 12 inches by 20 feet	Tank sides and bottom.
Do	3 pieces	2 by 12 inches by 3 feet	Tank ends and partition.
Lumber	70 linear feet	2 by 4 inches	Legs and crosspieces to tank.
Do	100 linear feet	1 by 4 inches	Leg braces and conveyor slides.
Lumber (finished)	36 linear feet	⅞ by 10 inches	Submerger paddles.
Do	15 linear feet	1 by 6 inches	Conveyor guards and submerger paddle ends.
Lumber (hardwood)	10 pieces	2 by 4 by 4 inches	Bearings.
Do	120 linear feet	1 by 1 inch	Conveyor slats.
Bolts	3	½ inch, 3 feet 7 inches long	Tank.
Pipe (iron)	25 feet	½ inch	Shafting.
Cast-iron pipe flanges	6	¾ inch	For paddle shafts.
Iron machine screws	2 gross	No. 8–32, 1 inch long	For conveyor slats.
Do	do	No. 8–32, 1½ inches long	Do.
Washers	4 gross		For machine screws.
Detachable link chain.	55 feet	No. 32	Driving mechanism for paddles and conveyors.
Attachment link chain.	22 feet	No. 45–K–1	For conveyors.
Sprockets [1]	3	12 inches, 33 teeth, ⅞-inch bore	For paddle drive.
Do.[1]	3	3¾-inches, 10 teeth, ⅞-inch bore	For conveyor drive.
Do.[1]	3	2 inches, 5 teeth, ⅞-inch bore	For driving mechanism.
Do.[1]	2	2 inches, 5 teeth, ½- or ¾-inch bore.[2]	For speed-reduction gear.
Do.[3]	8	3½ inches, 7 teeth, ⅞-inch bore	For conveyor.
Speed-reduction gear	1	48–1 or 50–1 reduction, with 4-inch or 3½-inch pulley.[4]	

[1] For no. 32 link chain.
[2] Depending on size of reducer driving-shaft.
[3] For no. 45–K–1 link chain.
[4] Depending on motor speed of 1,750 or 1,450 revolutions per minute, respectively.

If it seems desirable to construct a double-rinse section, as suggested on pages 11 and 19, the specifications given would require certain modifications. The single-rinse section shown in figure 1 is 7 feet long. With two rinse sections the length might well be reduced to 5 feet each; this would add 3 feet to the total length of the machine. The extra tank, of course, would make it necessary to construct an additional conveyor.

FLOOD-TYPE WASHERS

In most machines manufactured commercially the washing solution and rinse water is flooded over the fruit as it is conveyed through the machine by "walk-along" or "shuffleboard" conveyors or by rapidly rotating brushes. The flooding of the fruit is usually obtained either by impeller paddles that throw the solution over the fruit or by pumping the solution into a sluiceway above the fruit and allowing it to flow down through baffles. A shorter period of exposure of the fruit to the washing solution is required in flood machines than in flotation machines because of the more rapid renewal of the solution on the fruit in the flood machines. Sodium silicate can be used in flood machines but is relatively ineffective in flotation machines. Except for these advantages, flood machines without brushes are not appreciably more effective in removing spray residue than flotation machines when acid solutions are used.

Transverse, rotary underbrushes with the jute bristles or rubber fingers, when used in place of the walk-along conveyor in flood-type washers, have been found by experiment to appreciably increase residue removal. Efficiency has been increased in all types of wash

solutions, but the most outstanding results have been secured with the hydrochloric acid–mineral-oil wash and with solutions of sodium silicate. Certain mechanical difficulties have prevented the general adoption of brushes by washing-machine manufacturers, but the increase in cleaning efficiency through the use of brushes warrants their more general adoption.

The so-called "double-process" machines are essentially a combination of two flood machines. This combination permits of the use of two different washing solutions each followed by a rinse. Usually a sodium silicate solution is used in one wash tank and a hydrochloric acid solution in the other tank. Such machines may be necessary for fruit that it is very difficult to clean. The effectiveness of such machines might be increased if they were manufactured with rotating brushes instead of with other types of conveyors.

In most machines as now constructed the rinsing facilities are only about half as extensive as the washing facilities. This is probably sufficient when acid alone is used as the washing solution and when a liberal amount of fresh water is continually added to the rinse water. The increased use of wetting agents with acid solutions and of sodium silicate solutions makes rinsing more difficult and makes apparent the need for more adequate rinsing facilities. It would seem advisable under some circumstances to construct the machines with two rinse tanks. This might be of particular benefit where a limited supply of fresh water is available, in which case lime could be added to the first tank to neutralize the acid and as much fresh water as is available used in the second rinse tank. With two rinse tanks it would also be possible to use a disinfectant in the second rinse tank for the control of decay. Thus, Baker and Heald, in Bulletin 304 of the Washington Agricultural Experiment Station, suggest the use of a sodium hypochlorite solution with 0.4 percent available chlorine for 1 minute as an effective disinfectant for blue-mold spores.

WASHING SOLUTIONS

As already mentioned, the two materials that have proved most satisfactory for the removal of spray residues are hydrochloric acid and sodium silicate.

HYDROCHLORIC ACID SOLUTIONS

Washing solutions of hydrochloric acid are particularly applicable for fruit that has been sprayed with lead arsenate and lime or fungicides containing lime, with fruit sprayed with calcium arsenate, manganese arsenate, or fluorine compounds. It may also be used with apples that have not developed excessive wax and have been sprayed with lead arsenate alone (without lime) or with lead arsenate and spreader, fish oil, or soap.

For fruit washing the commercial grade of hydrochloric acid is used. *This acid is very corrosive, particularly in the concentrated form, and will burn the flesh and clothing unless immediately washed off with fresh water or an alkaline solution such as bicarbonate of soda or lime.* It should therefore be handled with great care, and it is advisable to keep on hand a supply of hydrated lime or baking soda in case of accident. The acid is usually obtained in 12-gallon

carboys, and a carboy-tilting frame or inclinator or an acid carboy pump will be found convenient in removing the acid from the carboy to smaller containers, which should be of glass, porcelain, or earthenware. The dilute solutions are less corrosive but will react readily with lime and cement and slowly with metal such as iron, copper, and tin. Where possible, therefore, metal parts of machines should be protected with heavy oil or paint, and concrete floors should also be so protected. When the acid-solution tanks are emptied the used solution should be kept out of irrigation ditches and away from trees and other useful plants. Where the waste acid is diverted to sewerage systems it is well to dilute it with copious quantities of water as it flows into the sewer and to flush the latter with water after the used solution has passed out.

The commercial grade of hydrochloric acid should test 20° Baumé, which indicates a solution of about 32 percent of actual acid in water. One gallon of 20° acid (specific gravity 1.16) contains about 3.1 pounds of hydrochloric acid. This, added to 100 gallons of water, makes a solution containing about 0.36 percent of acid by weight. A 1-percent solution, therefore, requires about 2.8 gallons of the concentrated acid to 100 gallons of water.

The strength of the acid solution can be readily determined by a simple titration method. For this, the following equipment and material are needed:

One 10-milliliter bulb pipette.

One 10-milliliter Mohr pipette graduated in 0.1 milliliter intervals.

One porcelain cup, glass tumbler, or small wide-mouthed bottle.

A standard solution containing exactly 23 grams of pure bicarbonate of soda per liter of water, and enough methyl-orange indicator to give the solution a distinct yellow color.

The pipettes can be obtained from any chemical supply house, and the standard soda solution can usually be made up by local druggists. The procedure is as follows: Using the bulb pipette, transfer 10 milliliters of the washing solution to the cup or tumbler. To accomplish this draw the acid solution by suction into the pipette until it is filled above the 10-milliliter mark. Hold the pipette between the thumb and fingers, leaving the forefinger free to place over the upper opening of the pipette as soon as it is withdrawn from the mouth. Permit the solution to drain slowly from the pipette (by rotating the pipette between the thumb and fingers while holding the forefinger lightly pressed against the upper opening) until the surface of the liquid reaches the mark on the upper stem. The pipette now contains 10 milliliters of acid solution which should be transferred to the glass tumbler or cup.

In a similar manner fill the graduated pipette with the standard bicarbonate solution, adjusting the level of the liquid to the 0.0 mark. Allow the bicarbonate solution to drain slowly into the 10-milliliter sample of wash solution in the tumbler, constantly shaking or stirring the latter solution. The methyl-orange will color the acid solution red until all of the acid has been neutralized by the bicarbonate solution, when the color will change to yellow. When this color change occurs, stop adding the bicarbonate solution and note the quantity of bicarbonate used. The number of milliliters used divided by 10 gives the percentage concentration of hydrochloric acid in the solution tested. For example, 3.6 milli-

liters of bicarbonate solution would indicate an acid concentration of 0.36 percent, which is equivalent to about 1 gallon of concentrated acid to 100 gallons of water.

The concentration of the acid wash solution can be increased to any desired point by adding concentrated acid to it at the rate of 1 quart per 100 gallons for each increase of 0.09 percent of acid desired. Thus, if the concentration in the tank is found to be 0.73 percent, and the concentration desired is 1.00 percent, it will be necessary to increase the concentration by 0.27 percent, and the addition of 3 quarts of concentrated acid for each 100 gallons of solution will be required.

During the washing process the hydrochloric acid reacts with the lime and other residues on the fruit, thus reducing the concentration of the acid. Some of the solution is carried out of the tank on the fruit and on certain types of conveyors. Water and acid must therefore be added at intervals to maintain the solution at the proper level and concentration. This can best be done by first adding the necessary water. After thorough mixing, test the concentration of the solution and add the required amount of acid.

The removal of spray residue from apples by washing with hydrochloric acid solutions is primarily a chemical reaction, and the completeness or effectiveness of the reaction will depend on the time of exposure of the fruit to the acid, the concentration and temperature of the solution, and the presence of fortifying agents that may assist either chemically or physically the action of the acid.

The time of exposure of the fruit to the acid is usually 30 to 60 seconds in flood-type machines and from 60 to 120 seconds in flotation-type machines. The longer exposures give more effective removal, but the shorter exposures are frequently used in order to obtain the maximum capacity of the machine.

The concentration of acid used ranges from 0.5 to 1.5 percent. The lower concentration is about the minimum that can be effectively used and is applicable only to lots of fruit that are relatively easily cleaned. Little additional cleaning is obtained by concentrations greater than 1.5 percent, and the use of concentrations above 1.5 percent places a greater strain on the rinse section.

When the maximum practicable time of exposure and concentration of acid are used and are not sufficiently effective in removing the residues, then the addition of fortifying agents or heating the washing solution or both must be resorted to.

The addition of 1 to 3 percent (8 to 24 pounds per 100 gallons) of common salt to cold or heated solutions of hydrochloric acid in many cases has resulted in the more thorough removal of arsenical residues, but it has relatively little effect on the removal of lead and has an inhibiting effect on the removal of fluorine residues.

The addition of 0.5 to 1.0 percent (4 to 8 pounds) of certain acid-resistant wetting or degumming agents has been found in most cases to increase greatly the effectiveness of either cold or warm acid washing solutions. There are a great variety of materials on the market that act as wetting agents. Some of these are proprietary preparations. These preparations are not usually pure compounds but are mixtures of materials the proportions of which may vary

somewhat from time to time, which may influence their effectiveness as aids in washing. Some of these are of no benefit in removing spray residues, and others injure the fruit.

Wetting agents act in a manner similar to soap in that they increase the wetting of the surface and may have a detergent action, thus physically removing some of the oil, wax, dirt, and spray material from the surface of the fruit. For this reason wetting agents are particularly applicable to oil-sprayed or waxy fruit. Wetting agents can be most conveniently used in flotation-type machines. In flood-type machines they cause excessive foaming. They can be used in such machines, however, by adding sufficient defoaming agent to control the foam. A defoaming agent consisting of a mixture of naphtha and wool grease is generally used for this purpose. When wetting agents are used with acid solutions heat or lenticel injury is more apt to occur than when acid alone is used; consequently, the temperature of heated solutions should be maintained at a slightly lower point with wetting agent and acid combinations. Likewise, rinsing needs to be more effective when wetting agents are used.

Wetting agents should not be used commercially until they have been tested and found to increase the efficiency of the washing solution without injuring the fruit. For specific information about wetting agents inquiries should be addressed to the United States Department of Agriculture or to State experiment stations.

The addition of an odorless kerosene or very light mineral oil of highly refined, white spray-oil type (viscosity 50 to 60 seconds Saybolt) at the rate of 1 gallon to 100 gallons to heated acid solutions has been found very effective with oil-sprayed or waxy fruit. Nonemulsified oil or kerosene, preferably the former, should be used. It is important that the oil be very light and have a viscosity as specified above, as a heavier oil may be detrimental rather than beneficial. It should also be emphasized that this washing treatment is only effective with solutions that are heated to 90° F. or above, and only in washers such as the flood or flood-brush machines, in which there is a distinct agitation of the washing solution. Salt may be added to such solutions to increase their effectiveness. A light mineral oil added to an acid solution reduces the danger from heat injury and allows higher temperatures to be used. This type of washing treatment has been used only under northwestern conditions, but it would probably also be effective under eastern conditions. Small amounts of the oil adhere to the surface of the fruit and are carried off. Quantitative tests for the amount of mineral oil present in the hydrochloric acid-mineral oil wash after various periods of operation have shown that the decrease in oil concentration due to carryover on the fruit is roughly one-half gallon per 100 gallons of solution every 3 hours at 110°. Thus, in order to maintain a fairly constant mineral-oil concentration, one-half gallon of oil per 100 gallons of solution should be added three times a day or at the following times: Middle of the morning, noon, and middle of the afternoon. At lower solution temperatures the carry-over of oil will be slightly greater because of its greater viscosity; at temperatures higher than 110° the carry-over, will be slightly less. The addition of greater amounts of oil to the solution ordinarily does not increase the cleaning efficiency though under certain conditions of cleaning it has been found necessary to add oil until the slightly oily appearance of the

fruit indicates that it has been effective in softening the residue and wax. Oil or kerosene used in the washing solution removes some of the oil or wax from the surface of the fruit. This may result in increased loss of moisture from the fruit and consequent shrivelling unless the fruit is held at relatively high humidities following such treatment.

Raising the temperature of the washing solution from room temperatures to 90° to 110° F. tends to soften the oily or waxy deposit on the surface of the fruit and may increase the speed of the chemical reaction and the solubility of the residues, thus increasing considerably the effectiveness of removal. The temperature that can safely be used will depend on the variety and condition of the fruit, the time of exposure to the solution, and the kind of solution used, as indicated on page 5.

SODIUM SILICATE SOLUTIONS

Heated solutions of sodium silicate have been found quite effective for removing the residue from apples that have been sprayed with lead arsenate and fish oil or with lead arsenate and mineral oil and from apples that have become waxy. Sodium silicate solutions are less effective than acid solutions for apples that have been sprayed with cryolite, calcium arsenate, manganese arsenate, or with lead arsenate and lime or fungicides containing lime. For this reason sodium silicate is not generally applicable to eastern conditions.

Sodium silicate can be obtained in a number of different forms. The form which has been commonly used for fruit washing and which has proved satisfactory for this purpose has a ratio of 1 part sodium oxide (Na_2O) to 1.58 parts silicon oxide (SiO_2) and has a sodium (Na) content of approximately 15 percent. This sodium silicate is obtained as a thick, very viscous clear liquid. It is alkaline in reaction and considerably less corrosive, particularly to metals, than is hydrochloric acid. However, it should be handled with care and the waste solution disposed of as directed for acid solutions.

Because of its very high viscosity it does not mix readily with water. For this reason it should first be mixed thoroughly with a small portion of water before being added to the water in the wash tank.

The concentration of the sodium silicate solution can be determined by titration in a manner similar to that used for testing an acid solution. The materials necessary are the same except that a standard acid solution is used instead of a standard soda solution. A 0.756 normal (2.75 percent) solution of hydrochloric acid, to which has been added sufficient methyl-orange indicator to give a distinct red color, should be used. A 10-milliliter sample of the sodium silicate solution to be tested is titrated with the standard acid solution until the red color is no longer changed to yellow. The number of milliliters of acid used multiplied by 10 gives the concentration of sodium silicate in pounds per 100 gallons. Thus, if 7.0 milliliters of acid are used, the concentration of sodium silicate is 70 pounds per 100 gallons. If a concentration of 80 pounds per 100 gallons is desired, 10 pounds of sodium silicate per 100 gallons would need to be added to the above solution. This determination

assumes that the sodium silicate has a sodium content of approximately 15 percent.

Sodium silicate solutions combine a solvent and detergent action and tend to remove dirt, oil, and wax from the fruit as well as to dissolve and wash the spray residue from the fruit. To be effective, sodium silicate solutions must be heated to 90° F. or above and must be used in machines in which there is a distinct agitation of the wash solution, as in flood-type washers.

Sodium silicate is commonly used at concentrations of 60 to 100 pounds of sodium silicate to 100 gallons of water and at temperatures of 90° to 120° F. The use of the higher concentrations may give somewhat more effective removal than the lower ones. More benefit, however, may be expected from the use of relatively high temperatures. Temperatures of 110° to 120° for exposures of 20 to 35 seconds are frequently used, particularly with apples that have been in storage. The temperatures that may be safely used are discussed on page 22.

As with the acid solution, certain fortifying agents may be used with sodium silicate solutions to increase their effectiveness in removing residues. For this purpose soap may be added in quantities sufficient to give as much foam as the machine will handle. In addition to soap, kerosene, or preferably a very light mineral oil (viscosity 50 to 60 seconds Saybolt) at the rate of 1 gallon to 100 gallons has been found of benefit. Rotating brushes under the fruit are of considerable benefit with sodium silicate solutions.

TYPE OF WASHER IN RELATION TO CLEANING SOLUTIONS

With flotation machines hydrochloric acid solutions only should be used. In such machines a wetting agent or a wetting agent and salt may be added for increased effectiveness. All of these solutions may be used at room temperature, or heated. The most effective cleaning in such a machine should be obtained by using the maximum practicable and safe concentration of acid, temperature of solution, and time of exposure, and adding a wetting agent.

With flood machines either hydrochloric acid or sodium silicate solutions may be used. The hydrochloric acid solutions may be fortified with either light mineral oil and salt or with a wetting agent and a defoaming agent, and the sodium silicate solutions may be fortified with soap or with soap and light mineral oil. The acid solutions either with or without the wetting agent can be used either at room temperature or heated. The acid solutions with oil and the sodium silicate solutions must be warmed to be effective.

With flood machines having brushes the same solutions may be used as in flood machines without brushes; however, the brushes will be most effective with the sodium silicate solutions or with the acid-oil combination.

With dual-process machines the same solutions may be used as indicated for flood machines. Although hydrochloric acid solutions or sodium silicate solutions can be used in both wash tanks of such machines, the most effective removal is generally obtained by using a sodium silicate solution in the first tank and an acid solution in the second for oily or waxy fruit that has not been sprayed with lime or alkaline materials. More effective residue removal from fruit that

has been sprayed with a mixture containing lime would probably be obtained by having the acid solution in the first compartment and sodium silicate in the second. If sodium silicate is used in the second compartment a more effective final rinse is required than is necessary when acid is used in the second compartment.

METHODS OF WARMING THE WASHING SOLUTIONS

As has been indicated previously, some of the washing solutions must be warmed to be effective, and the effectiveness of others may be increased by warming. The washing solution may be heated by means of electric immersion heaters, by releasing live steam in the solution, by placing hot-water or steam coils in the solution, or by circulating the washing solution through hot-water heaters.

A convenient method of heating the solution is by means of acid-resistant bayonet-type electric heaters that are inserted in the washing solution. One heater of about 8-kilowatt capacity will be needed for each 100 gallons of washing solution. Electric heaters can be thermostatically regulated so as to maintain a constant temperature without hand regulation. The installation of electric heaters usually requires a larger transformer to give the power requirement and necessitates some extra wiring, all of which increases the expense of heating by this method. The operation of the heaters consumes considerable power so that if the power rate is high the convenience of heating by this method is more than offset by the additional cost as compared with that of heating by other methods.

Releasing live steam directly into the washing solution has been found a convenient and practical method of warming the solution. A steam boiler that can be used for this purpose is frequently available so that no immediate expenditure for equipment is necessary except for sufficient piping or hose to carry the steam from the boiler to the wash tank. By releasing the steam at several points in the tank more even heating can be obtained. Because condensation of the steam tends to dilute and weaken the washing solution, the concentration of the solution must be tested at frequent intervals and the necessary materials (hydrochloric acid or sodium silicate and fortifying agents) added to maintain the desired concentration.

Where a small boiler or hot-water heater is available, or where low-pressure steam is required for other purposes, the solution can be warmed by means of a coil in the wash tank through which the steam or hot water is circulated. If hot water is used, a small pump is needed to circulate it through the coils. It is not necessary to build up a system of coils in the wash tank; a pipe may simply be given a turn about the tank and brought out at the opposite end. Inlet and outlet valves are provided for controlling the flow of steam or hot water through the tank in order to regulate the temperature of the cleaning solution. This method of heating should be more applicable to sodium silicate solutions as acid solutions would attack the coil and make necessary its replacement from time to time. Monel or other acid-resistant metal may be used for steam coils in acid solutions. If welded joints are used, rather than threaded connections, coils of this type will give several seasons' service in heated acid solutions.

One of the least expensive methods of warming the solution is by circulating it through coils in an improvised stove. An ordinary 50-gallon oil drum, costing about $3 to $5, may be used as a stove by cutting a door in one end, laying it on its side on a fireproof stand (such as a box of sand), and fitting a stovepipe into the upper side. A coil of 1-inch wrought-iron pipe is placed within the drum, bent so that it lines one side and the top of the stove, with the intake at the bottom of the stove and the outlet at the top, thereby favoring the natural circulation of the liquid within the coil. If possible the pipe should be coiled into the desired shape rather than made by the use of fittings. The fewest possible sharp turns in the system, the use of bends in the pipe instead of fittings, and the installation of pipe no smaller and not much larger than 1 inch in diameter will facilitate the warming of the liquid and will minimize corrosion. Four or five turns of pipe in the stove should be sufficient, giving about 15 feet of heating coil. Because of the corrosive effect of the warm acid solution it will be necessary to replace the coil occasionally, but this expense should not exceed $5. The total cost of such a system has been from $15 to $20.

Wood has been satisfactorily employed for fuel in the heater. If coal is used, some sort of grate may be necessary. It will usually be necessary to begin circulating and warming the acid solution an hour or two before the cleaning is to begin. This type of heater generally does not have a capacity adequate for the larger sizes of commercial washing machines.

In a flotation washer the solution cools at a slower rate than in machines where it is agitated and aerated by paddles or pumps. While home-made heating plants may be used for such machines in the smaller-sized orchards, they have not been satisfactory where large quantities of fruit are to be washed, where flood-type machines are to be used, or where it is necessary to use temperatures between 100° and 120° F. Under these circumstances, where rapid heating and a close control of temperatures are necessary, a steam boiler is a necessity, and thermostatic control is most important to insure uniformity in removal and the avoidance of injury from excessive temperatures.

THERMOSTATIC CONTROL OF HEATING

With the increased use of heated solutions a thermostat that automatically controls the steam valve has become an essential part of the heating equipment. Some ideal heating plants have been made by fitting an automatic oil burner on an old threshing-engine boiler and placing a thermostat on the steam line between the boiler and the washing machine. The temperature of the washing solution controls the steam valve and the steam pressure in the boiler controls the automatic oil burner, so that as long as fuel oil and water are furnished to the boiler the temperature of the washing solution remains constant for an indefinite length of time.

Boilers may be secured with this equipment installed as well as with automatic water injectors.

RENEWAL OF THE WASHING SOLUTION

During the washing process dirt and decay spores are continually washed from the fruit. The removal of the decay spores by fresh

wash solution and rinse water would tend to improve the keeping quality of the fruit. The decay spores, however, accumulate in the wash solution until they become a hazard to the fruit being washed. Likewise the arsenic and fluorine is removed from the fruit in a soluble form and accumulates in the wash tank. This soluble arsenic and fluorine will burn the skin of the apples unless completely removed by the rinse water. A heavy accumulation of arsenic or fluorine in the wash tank may overtax the rinsing facilities. Because of this accumulation of soluble residues, decay spores, and dirt, it is necessary that the used solutions be drained from the wash tank and fresh solution be added after the tank is cleaned. This should be done after each day's run or after about 1,000 to 1,500 bushels of fruit per 100 gallons of solution have been washed.

RINSING THE FRUIT

Proper rinsing of the fruit is a very important part of the washing process and can do much toward eliminating the danger of injury from the washing solution or soluble residues and decay spores in the washing solution. For effective rinsing at least 2 gallons of fresh water per bushel of fruit washed should be added to the rinse tank as a spray on the fruit as it leaves the tank. When sodium silicate is used as the washing solution, or when wetting agents or mineral oils are added to hydrochloric acid solutions, more thorough rinsing is required than when hydrochloric acid only is used in the washing solution. Fruit washers are generally constructed with the rinse section only about half as large as the wash section. This is usually sufficient when hydrochloric acid alone is used as the washing agent, but larger rinse sections are desirable when sodium silicate is used or wetting agents or mineral oils are added to the hydrochloric acid.

When an acid solution is used and the supply of fresh water is limited, less than 2 gallons for each bushel of fruit washed, the same rinse water can be used continuously by adding sufficient lime to maintain the rinse water in a neutral or slightly alkaline condition. The lime neutralizes the hydrochloric acid carried over on the fruit and renders insoluble the arsenic remaining on the fruit after washing. Usually 2 pounds of slaked lime or broken limestone to 50 gallons of rinse water is sufficient. As the lime becomes exhausted by the acid, additional lime must be added at intervals. The rinse water can be tested with red litmus paper which should turn blue in the rinse water. If it remains red it indicates that the rinse water is acid, and more lime must be added. A simple method of testing the effectiveness of rinsing when an acid-wash solution is used is to taste the water in the calyx basin of the apples as they leave the rinse section. A slightly sour taste indicates that the acid has not been completely neutralized or rinsed off.

It is important that apples turn over in the rinse section so that the calyx basin is thoroughly rinsed.

For more effective rinsing it would seem desirable that washing machines be constructed with two rinse sections, particularly where the supply of rinse water is inadequate. It would then be possible to add lime to the first rinse section, using this water continuously, and in the second rinse section fresh water only could be used to the

extent that it is available. When lime is used in the rinse tank the water should be drained out and renewed as frequently as possible.

DRYING THE FRUIT

If sound fruit is used, and if the washing and rinsing operations are carefully done, drying the fruit is not essential to protect its keeping quality, although it may be desirable in order to facilitate packing. In most commercial machines the drying is accomplished by means of absorbent cloths that are drawn over the rotating fruit and absorb the excess moisture. The water is then removed from the cloths by means of a wringer through which the cloths are squeezed. This treatment is also effective for removing insect specking, dirt, and other residues not removed by washing. Such driers

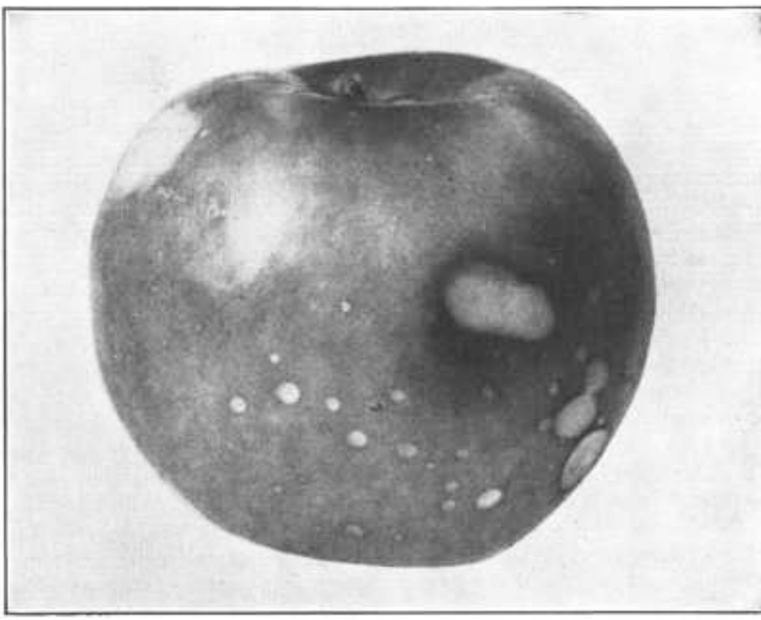

FIGURE 3.—Apple showing typical acid burning.

can be obtained as separate units to be used with home-made washers if drying is considered sufficiently important to justify the expense.

EFFECT OF WASHING ON KEEPING QUALITY

The washing of sound apples, when properly done, does not impair their keeping quality. Although certain injuries do sometimes occur from washing, these can be avoided by observing certain precautions. Injuries that may result from washing may be listed as hydrochloric acid burning, arsenic or fluorine injury, heat injury, alkali injury, handling injuries, and decay.

Hydrochloric acid injury consists of a bleaching of the skin, usually in small spots around the lenticels and frequently accompanied by cracking through the center of the affected area (fig. 3). With age,

the injured area becomes depressed but remains a light tan or yellowish color unless arsenic is present, in which case it becomes darkened. Hydrochloric acid injury is very seldom encountered in commercial operations and usually results from prolonged exposure of the fruit to the acid, as during a shut-down of the machine or through failure of some of the fruit to progress through the machine normally. It can be prevented by keeping the apples out of the washing section when the machine is not running and by repairing the machine so as to insure positive progression. Rinsing that is sufficiently thorough to prevent arsenic or fluorine injury will also prevent acid injury.

During the washing process arsenic from arsenical sprays or fluorine from fluorine sprays is released in soluble forms that are toxic to the skin of the fruit and unless thoroughly rinsed off may cause injury. This injury (fig. 4) consists of a browning or blackening of the skin

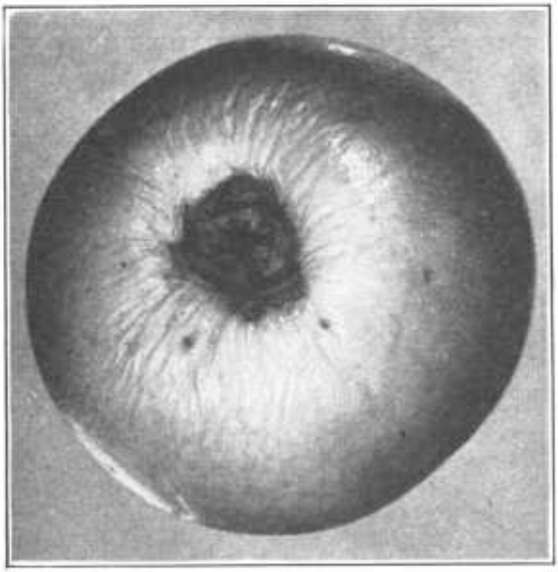

FIGURE 4.—Apple showing typical arsenical injury.

usually in the calyx basin but sometimes in the stem cavity. The injury may not develop for 1 to 2 weeks after the washing. At first the injury is superficial, but in advanced stages it becomes depressed and may extend an eighth of an inch or more into the flesh. Such injury opens the way for the development of decay organisms. Arsenical and fluorine injury can be avoided by changing the wash solution at intervals so that the soluble arsenic or fluorine does not become too concentrated in the wash solution and by thorough rinsing with fresh water or with limewater.

It should be mentioned that arsenical-spray burning, even though it does not show up until after washing, may have been caused by orchard conditions rather than by washing. Wet weather during harvest and particularly with picked fruit that is standing in the orchard may start burning that does not become apparent until after the fruit is washed.

Heat injury (fig. 5) consists of a latitudinal checking or cracking of the skin usually around the calyx but sometimes on the cheek of the apples. This injury may be apparent within a few minutes after washing. The cracking of the skin results in excessive shriveling in storage and forms entry points for decay organisms. Heat injury can be prevented by careful control of the temperature and time of exposure. The temperature and time of exposure that can safely be used depends on the variety and condition of the fruit and the washing solution used. In general, a temperature of 100° F. can be used for exposures of 1 minute or less without injury. With tender-skinned varieties such as McIntosh and Esopus Spitzenburg and to a less extent York Imperial and Jonathan, lower temperature or shorter exposures should be used than with tougher-skinned varieties such as Winesap. Fruit that is turgid, as it is likely to be immediately after picking, particularly following wet or cloudy

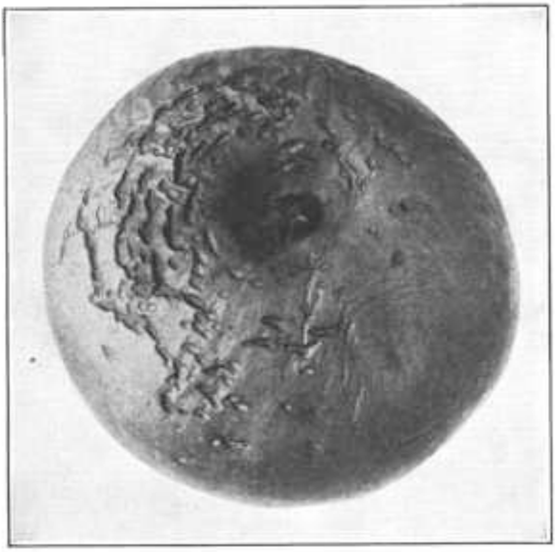

FIGURE 5.—Apple showing typical heat injury.

weather, is more susceptible to heat injury than fruit that is slightly shriveled as after a period in storage. Higher temperatures can generally be used with sodium silicate solutions and acid solutions to which mineral oil has been added than with solutions of acid alone. Temperatures of 115° to 120° for 20 to 35 seconds' exposure are frequently used with sodium silicate solutions, particularly when washing apples that have been in storage. When wetting agents are used with hydrochloric acid, somewhat lower temperatures should be employed than when acid alone is used.

The skin of the apple is its chief protection against the entrance of decay organisms. If the fruit is handled roughly so that the skin is punctured or broken and washed with an old solution that has become heavily contaminated with decay spores, a large percentage of decay during storage is likely to follow. However, by changing the wash solution daily, by copious rinsing with clean

water, and by careful handling of the fruit, the decay in apples may be reduced as a result of washing.

ANALYSIS OF FRUIT

Because of the many factors that influence the ease of spray-residue removal, such as the spray treatment, climatic conditions, variety, and maturity of fruit, it is impossible to state what washing treatment will satisfactorily clean a given lot of fruit. Experience may indicate approximately the washing treatment that should be used, but the fruit must be analyzed after washing to determine whether the washing treatment has been effective. Since the amount of residue retained during the growing season varies with different varieties, and the ease of removal by washing varies with the variety and maturity, it is necessary that each variety be analyzed separately, as a washing treatment that is effective for one variety may not be for another even though both received the same spray treatment. Likewise, it is necessary that a variety be analyzed at intervals as the ease of removal may change with maturity and a washing treatment that is effective with early picked fruit may not be with late-picked fruit. In choosing a sample for analysis, fruit of the smallest size and that which appears to have the most residue should be taken, as this is the type of fruit that is likely to be selected by those responsible for the enforcement of spray-residue tolerances. It is important that the analyses be made by a competent chemist. With fruit sprayed with lead arsenate it is more important that the lead residue be determined than the arsenic residue, as any treatment that effectively removes the lead will almost certainly be effective for the arsenic also.

COST OF WASHING

The cost of washing apples varies considerably, depending on the size of the crop, the difficulty of removing the spray residue, the cost of analysis, and other factors. With fruit that is difficult to clean, requiring heated solutions, dual-process machines, and frequent analyses, the cost may be as much as 5 cents or more per box. With a large crop of apples that are easily cleaned, requiring only simple, inexpensive washing equipment and relatively weak solutions at room temperature, the cost may be less than 1 cent per bushel.

WASHING PEARS

In general, the methods and directions for washing apples are applicable to pears and other fruits also. However, some fruits require special treatment in certain respects, and therefore some special consideration will be necessary.

Pears do not generally require as heavy spray applications as apples and are therefore more easily cleaned. Hydrochloric acid solutions are generally indicated for washing pears. Sodium silicate solutions should not be used for washing russet varieties of pears, such as Bosc and Winter Nelis as it causes a distinct darkening of the russet areas, but it may be used with pears that are not russeted.

Flotation-type washers are not well suited for washing pears as most varieties will not float in the acid solutions or in water. A

modification of the flotation-type machine can be used by installing rubber-belt conveyors the entire length of the acid and rinse tanks. It is also possible to use a flotation machine by having a conveyor running the entire length of the rinse tank and adding a salt concentration of about 10 percent (80 pounds to 100 gallons) to the wash solution to cause the pears to float.

Some varieties of pears such as Anjou and Comice have very tender skins and must be handled with extreme care in order to prevent skin breaks. The use of dry-cleaning equipment such as brushers or wipers is especially hazardous with such varieties and may produce skin scratches and abrasions. Pears usually can be effectively cleaned with acid solutions at room temperatures. Kerosene or other mineral oils should never be added. When heated solutions are necessary temperatures as high as those suggested for apples may safely be used.

CLEANING PEACHES

Peaches are usually sprayed with lead arsenate to control the plum curculio and the oriental fruit moth. Such sprays are applied while the fruit is still very small, and no excessive residues are likely to remain on the fruit at harvest. Dry-wiping machines are frequently used to remove the fuzz or pubescence from peaches, and such treatment also removes considerable spray residue from fruit that has been sprayed late in the season. Peaches cannot be washed with hydrochloric acid solutions as severe acid injury is sure to follow such treatment.

WASHING CHERRIES [1]

Cherries are frequently sprayed with lead arsenate for the control of the cherry fruit fly. Such sprays are usually applied early in the season, and residues in excess of the tolerances are not generally encountered. Lead arsenate residues have been removed from sweet cherries by washing with dilute hydrochloric acid solutions and rinsing with fresh water. There was no increase in decay following such treatment nor was there any splitting of the fruit, provided the washing did not take place until several hours after picking. Sweet cherries can be washed in dipping tanks by placing the fruit in small slatted crates with about a quarter of an inch space between the slats. Sweet cherries might also be washed in some types of commercial washers in which conveyors such as the walk-along type are used that would carry flat slatted crates through the machines. Washing in water as practiced in most canneries removes considerable amounts of spray residue and may be sufficient treatment for either sweet or sour cannery cherries that have residues only slightly in excess of the tolerances.

Although the washing treatments indicated for sweet cherries would no doubt be effective in removing spray residue from sour cherries also, it is doubtful whether they could be used without injury to the shipping and keeping quality of the softer textured sour cherries intended for the fresh-fruit markets.

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[1] See Oregon Agricultural Experiment Station Bulletin 298, Arsenical Spray Residue on Cherries.

WASHING GRAPES [2]

Control of the grape berry moth in certain sections of the United States is accomplished by spraying with lead arsenate, and spray residues at harvest in excess of the tolerances may result. Grapes have been found to carry residues considerably in excess of the tolerances when given only two applications of lead arsenate, the last application being applied shortly after blossoming. Spray residues have been effectively removed from American varieties of grapes by washing in dilute solutions (0.5 to 1.0 percent) of hydrochloric acid at room temperature and rinsing with fresh water. The washing can be accomplished in dipping tanks or in commercial machines with suitable conveyors by means of slatted crates, as suggested for cherries.

Because of the bunched condition of the fruit it cannot be effectively and quickly dried. If the wet grapes are packed in large containers, such as bushel or half-bushel baskets, drying out will be very slow, and excessive mold and decay is likely to result, particularly if there are many cracked berries. For the fresh-fruit trade, therefore, grapes that are to be washed must be handled with great care and should be packed in baskets of 12-quart size or less. Holding the grapes at low temperatures (32° to 40° F.) will greatly reduce mold development.

WASHING CURRANTS

Currants are sometimes sprayed with lead arsenate to control the currant worm. Because of the very small size of the berries and the large proportion of stems, one application of lead arsenate applied more than a month before picking is likely to result in residues in excess of the tolerances. Such residues can be effectively removed by washing with solutions of hydrochloric acid (0.5 to 1.5 percent) at room temperature, followed by rinsing with fresh water.

Currants intended for the fresh-fruit markets are usually shipped in crates. To avoid extra handling the currants should be washed in the quart boxes in which they are to be shipped, by placing the boxes in flat slatted crates and dipping them in the acid solution and rinse water, or by means of commercial fruit washers with suitable conveyors, as suggested for grapes and cherries. If washed in a flood-type machine it is necessary to cover the currants with cheesecloth to keep them from being splashed out of the boxes.

As with grapes, it is not feasible to dry the currants effectively and quickly after washing. The moisture in the boxes is favorable to the development of mold, particularly if there are many cracked or mashed berries and if they are held at high temperature. However, washing need not materially increase decay and mold provided the berries are sound, very carefully handled, and shipped under refrigeration or under conditions that permit of rapid drying.

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[2] Recommendations are based on Studies on the Removal of Spray Residue from Grapes, by J. M. Lutz and G. A. Runner, published in American Society of Horticultural Science Proceedings, vol. 29, pp. 345–349, 1933.

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